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EVALUATION OF MORPHOLOGICAL AND BIOCHEMICAL CHARACTERISTICS AND PRODUCTIVE POTENTIAL IN PEAS (*PISUM SATIVUM* L.) GENOTYPES UNDER ECOLOGICAL CONDITIONS SPECIFIC TO THE CRIȘURILOR PLAIN

Ovidiu C. UNGUREANU[1], Iulian O. STANA[1], Elena UNGUREANU[2], Maria E. FORTUNĂ[3], Bogdan M. TOFĂNICĂ[2], Paul A. BĂRBĂTEI[1], Viviane BOTA[1], Violeta TURCUȘ[1,4]

[1]"Vasile Goldiș" Western University of Arad, Romania
[2]"Ion Ionescu de la Brad" Iasi University of Life Science, Iași, Romania
[3]"Petru Poni" Institute of Macromolecular Chemistry, Iași, Romania
[4]National Institute for Economic Research "Costin C. Kiritescu" of the Romanian Academy/Centre for Mountain Economy (CE-MONT), Vatra Dornei, Romania

Abstract: Peas (*Pisum sativum* L.) are a strategic crop due to their agro-industrial and economic value, contributing not only to human nutrition and animal feed but also to crop rotation diversification through biological nitrogen fixation, thereby improving soil fertility and reducing the need for chemical fertilizers. The present study (conducted between 2023 and 2025) comparatively evaluated the performance of six pea genotypes (Anastasia, Evelina, Rodica, Aurora, Nicoleta, and Xantos) to identify genotypes with high ecological plasticity, superior productive potential, and optimal agronomic quality, in the context of thermal and rainfall variability and episodes of water stress. Agrobiological and technological indicators relevant to the agri-food sector were analyzed: growing season, plant height, seed yield, percentage of dry pods, 1000-seed weight, hectoliter weight, and protein, starch, lipid, and ash content. The results provide useful information for selecting suitable genotypes for the Crișurilor Plain and for optimizing cultivation technologies, with an impact on increasing production and strengthening sustainable agricultural systems.

Keywords: *Pisum sativum* L., morphology, genotypes, productivity, sustainability.

INTRODUCTION

Peas (*Pisum sativum* L.) are a strategically important crop due to their high nutritional value (protein, fiber, vitamins, minerals, and bioactive compounds) and ecological adaptability; they have been cultivated for fresh or dried seeds for over 8,000 years (Axinte *et al*., 2002; Wu *et al*., 2023).

Globally, it occupies 14–16 million hectares, with annual yields of 14–15 million tons of dry seeds, with Canada and China being the main producers (Raghunathan *et al*., 2017).

In the European Union, peas are considered a strategic crop for the sustainability of crop rotations and the reduction of nitrogen fertilizers (Kadžiulienė *et al*., 2025).

From an agroecological perspective, peas thrive in fertile, well-drained soils and biologically fix atmospheric nitrogen through symbiosis with *Rhizobium leguminosarum*, contributing to soil fertility and the diversification of agricultural systems (Plaza-Bonilla *et al*., 2017; Kadžiulienė *et al*., 2025).

It is also an excellent cover crop in crop rotation, reducing pest and disease infestation. Climate change and water or heat stress can limit productivity, which justifies the selection of genotypes with increased tolerance and stability under local conditions (Smýkal *et al*., 2017).

In this context, the present study evaluated, under the conditions of the Crișurilor Plain, six pea genotypes (Anastasia, Evelina, Rodica, Aurora, Nicoleta, Xantos), by analyzing agrobiological and technological traits (growing season, plant height, seed yield, percentage of dry pods, 1,000-seed weight, hectoliter weight), to identify the genotypes with the best adaptability and yield stability for the development of sustainable agriculture.

MATERIALS AND METHODS

The research was conducted at the experimental field of the Arad Cattle Breeding Research and Development Station (S.C.D.C.B. Arad) over three consecutive growing seasons, from 2023 to 2025. The soil on which the experiment was conducted is alluvial, with a medium loamy texture and a granular–agglomerated structure (pH = 7.0–7.1; organic matter = 3.4–3.6%; clay = 23–24%; available phosphorus = 13.2–13.5 mg/100 g soil; total nitrogen = 0.15–0.17 mg/100 g soil; groundwater depth = 50–60 cm), characteristics favorable to root system development and the normal physiological processes of plants (Ungureanu *et al*., 2021; 2024).

The experimental plots had an area of 25 m² (L = 10 m, W = 2.5 m), with a buffer zone of 1.0 m, 1.0 m between replicates, and 0.5 m between treatments (Samuil *et al*., 2025).

Soil preparation consisted of: autumn plowing to a depth of 25 cm, followed by leveling the field and keeping it free of weeds until sowing; preparing the seedbed with a cultivator equipped with arrow-shaped tines to a depth of 5 cm; sowing in the first ten days of March, as soon as weather conditions allowed entry into the field.

The seed used had a purity of 98% and a germination rate of 93%, and the seeding rate was 125 viable

***Correspondence**: Ungureanu Ovidiu Costica, Vasile Goldis Western University, Faculty of Medicine, Biology Department, Str. Liviu Rebreanu, No 91-93, Arad, Romania, email: ovidiu.c.ungureanu@gmail.com*

seeds/m², with a row spacing of 12.5 cm and a seeding depth of 5 cm. The seed rate ranged from 250 to 280 kg/ha, values considered optimal for achieving an appropriate plant density (Axinte *et al*., 2002).

The experiment was designed as a single-factor design with six treatment variants (V1 – Anastasia, V2 – Evelina, V3 – Rodica, V4 – Aurora, V5 – Nicoleta, V6 – Xantos), each variant being replicated four times, in accordance with classical experimental design (www.madr.ro/ISTIS, 2023).

Data processing was performed by calculating mean values, in accordance with established methodologies for the analysis and interpretation of results in the field (Samuil *et al*., 2025).

RESULTS AND DISCUSSIONS

An analysis of data on average temperature and precipitation values for the period 2023–2025 (Figures 1–3) reveals a general warming trend in the Arad area, accompanied by significant year-to-year variations in precipitation. In 2023 (Figure 1), temperatures were high as early as spring, and precipitation was unevenly distributed, with periods of deficit between April and June. The year 2024 (Figure 2) was characterized by exceptionally high temperatures and prolonged heat waves, exacerbating soil drought. In 2025 (Figure 3), temperature conditions were approximately normal, and precipitation distribution was uneven, with periods of deficit during the growing season. These climatic conditions support observations regarding thermal and water stress on the pea crop (*Pisum sativum* L.), highlighting the importance of adapting cultivation technologies to maintain production stability.

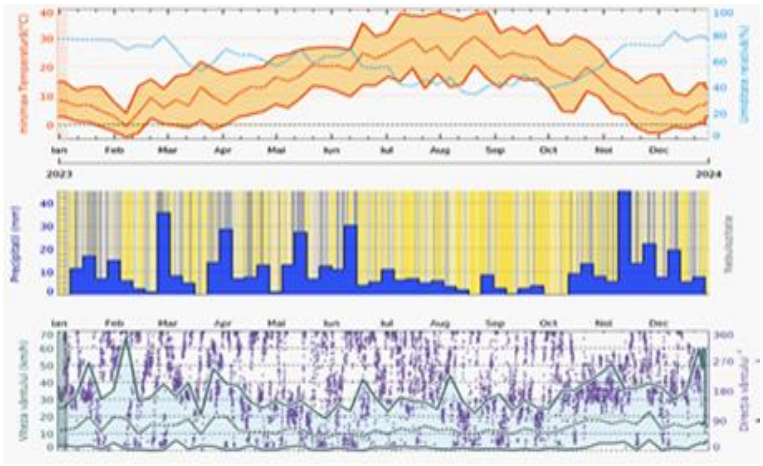

Fig. 1. Average temperature and precipitation values: 2023 in Arad.
Source: https://www.meteoblue.com Weather Archive Arad

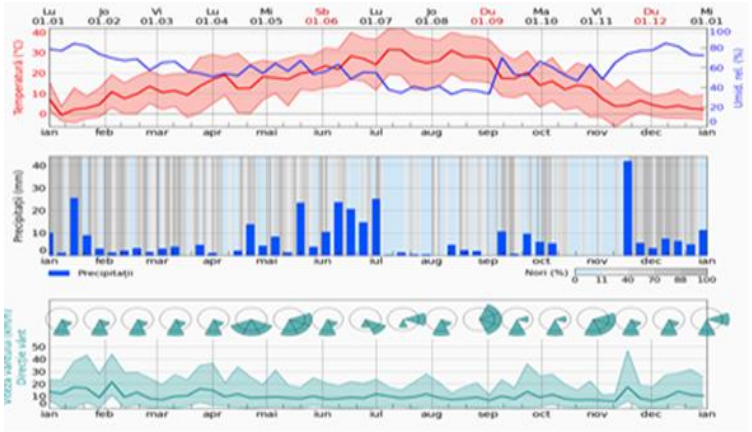

Fig. 2. Average temperature and precipitation values: 2024 in Arad.
Source: https://www.meteoblue.com Weather Archive Arad

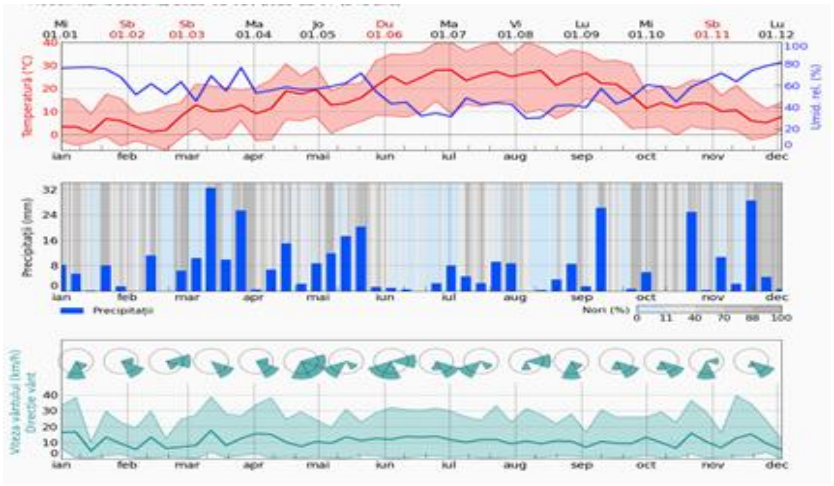

Fig. 3. Average temperature and precipitation values: 2025 in Arad.
Source: https://www.meteoblue.com Weather Archive Arad

The growing season of the analyzed pea genotypes ranged from 80 to 92 days between 2023 and 2025, highlighting both the genetic characteristics of the biological material and the influence of environmental conditions on the plants' growth rate. The shortest average growing season was recorded for the Anastasia genotype (81 days), followed by the Evelina genotype (83 days) and Aurora (86 days), indicating a potential for relatively early maturity. The genotypes Nicoleta (88 days) and Rodica (90 days) had an intermediate duration, while the Xantos genotype (the control) exhibited the longest growing season (91 days). The small variations between years suggest relatively good stability of this trait, but the observed differences reflect the genotypes' physiological response to soil and climate factors, which influence plant growth, differentiation, and maturation processes (Table 1).

Table 1.

The Influence of Environmental Conditions on the Growing Season of Peas

No.	Genotype	Vegetation period (days)			
		year 2023	year 2024	year 2025	average 2023-2025
1	Anastasia	82	81	80	81
2	Evelina	84	83	83	83
3	Rodica	90	91	90	90
4	Aurora	86	86	85	86
5	Nicoleta	88	87	88	88
6	Xantos (control)	92	91	90	91

The height of the pea plants ranged from 65 cm to 77 cm between 2023 and 2025, highlighting differences attributable both to the genetic potential of the genotypes and to the influence of environmental conditions during the study years. The highest average height was recorded for the Evelina genotype (76 cm), exceeding the Xantos control genotype (68 cm) by 9 cm, indicating superior vegetative capacity and good adaptation to soil and climate conditions. Intermediate values were observed in the Rodica and Nicoleta genotypes (72 cm each, +4 cm compared to the control) and Aurora (70 cm, +2 cm compared to the control), while the Anastasia genotype had the lowest average height (66 cm, −2 cm compared to the control). The relatively low variability across years suggests good stability of this morphological trait, with plant height resulting from the interaction between genetic factors and environmental conditions that influence growth and vegetative development processes (Table 2).

Table 2.

The Influence of Environmental Conditions on Plant Height in Peas

No.	Genotype	Plant height (cm)				Difference (cm)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	66	65	67	66	- 2
2	Evelina	77	77	75	76	9
3	Rodica	72	73	72	72	4
4	Aurora	70	70	71	70	2
5	Nicoleta	73	72	72	72	4
6	Xantos (control)	69	67	67	68	CTRL

The data obtained highlight the variable influence of soil and climate conditions on organic pea seed production during the 2023–2025 period. The Anastasia genotype recorded the highest average (3,320 kg/ha), with a slight annual increase from 3,210 kg/ha in 2023 to 3,360 kg/ha in 2025, indicating good adaptability to environmental changes. The Evelina genotype showed high stability, with yields of 3,250–3,300 kg/ha, close to the control genotype Xantos (3,260 kg/ha), demonstrating greater tolerance to soil and climate variations. In contrast, the Rodica and Aurora genotypes showed a progressive decline in yield over the three years (3,080 kg/ha and 3,060 kg/ha on average), while the Nicoleta genotype exhibited moderate fluctuations (3,160 kg/ha on average). These results suggest genetic differences in adaptability to ecological conditions and highlight the need to select genotypes with stable performance for organic farming (Table 3).

Table 3.

The Influence of Soil and Climate Conditions on Organic Yield and Seed Production in Peas

No.	Genotype	Production (Kg/ha)				Difference (Kg/ha)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	3210	3380	3360	3320	60
2	Evelina	3250	3270	3300	3270	10
3	Rodica	3050	3100	3080	3080	-180
4	Aurora	3110	3060	3010	3060	-200
5	Nicoleta	3270	3150	3060	3160	-100
6	Xantos (control)	3260	3270	3250	3260	CTRL

The results obtained demonstrate the influence of environmental conditions on the percentage of dry fruit (pods) in peas during the 2023–2025 period. The Anastasia genotype exhibited the highest average percentage of dry fruit (7.5%), with a slight increase from 7.4% in 2023 to 7.6% in 2025, indicating good adaptability to environmental variations. The Evelina genotype demonstrated high stability, with constant values of 7.4–7.5%, close to the Xantos control genotype (7.4%), suggesting greater tolerance to environmental conditions. In contrast, the Aurora genotype recorded the lowest average (7.2%), while the Rodica and Nicoleta genotypes showed minor fluctuations (-0.1%), highlighting reduced genetic differences in response to environmental factors. These results underscore the importance of genotype selection not only for total yield but also for seed quality, assessed by the percentage of dry fruits (pods), which is essential in organic farming (Table 4).

Table 4.

The influence of environmental conditions on the percentage of dry fruit (pods) in peas

No.	Genotype	Percentage of dried fruit (%)				Difference (%)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	7.4	7.5	7.6	7.5	0.1
2	Evelina	7.4	7.4	7.5	7.4	0.0
3	Rodica	7.3	7.3	7.4	7.3	-0,1
4	Aurora	7.2	7.3	7.2	7.2	-0.2
5	Nicoleta	7.3	7.4	7.3	7.3	-0.1
6	Xantos (control)	7.5	7.4	7.4	7.4	CTRL

The data presented indicate the influence of varying environmental conditions on the 1,000-seed weight (TSW) of the pea genotypes studied between 2023 and 2025. Analysis of the values shows that the Evelina and Nicoleta genotypes recorded steady increases in TSW compared to the multi-year average, with values of 20 g and 11 g, respectively, suggesting greater adaptability to the ecological factors during this period. In contrast, the genotypes Anastasia and Rodica showed significant decreases (-11 g and -16 g), indicating greater sensitivity to climatic and soil variations. The control genotype Xantos maintained a stable average value (242 g), providing a reference point for evaluating the performance of the other genotypes. These differences suggest that the selection of genotypes with high and stable TSW is essential for optimizing pea production under variable environmental conditions (Table 5).

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Table 5.

The influence of environmental conditions on the 1,000-seed weight (TSW) of peas

No.	Genotype	TSW (g)				Difference (g)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	228	234	230	231	-11
2	Evelina	258	265	262	262	20
3	Rodica	230	226	222	226	-16
4	Aurora	237	244	240	240	- 2
5	Nicoleta	249	260	251	253	11
6	Xantos (control)	240	246	241	242	CTRL

The hectoliter weight (HW) values of the pea seeds showed moderate variability across genotypes and years, suggesting a clear interaction between genetic potential and the environmental conditions of the growing environment. The Rodica and Nicoleta genotypes exhibited the highest average HW values (77 kg/hl), slightly exceeding the control genotype Xantos, indicating a better ability to utilize soil and climate conditions. Overall, the relatively small differences between genotypes suggest physiological stability of the trait, with hectoliter weight being influenced both by the processes of reserve substance accumulation in seeds and by annual variations in ecological factors (Table 6).

Table 6.

The influence of environmental conditions on the hectoliter weight of peas (HW)

No.	Genotype	HW (kg/hl)				Difference (kg/hl)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	74	78	76	76	0
2	Evelina	73	77	75	75	-1
3	Rodica	75	79	77	77	1
4	Aurora	74	77	75	75	-1
5	Nicoleta	76	78	77	77	1
6	Xantos (control)	74	78	76	76	CTRL

The protein content of pea seeds ranged from 24.7% to 26.4% during the period analyzed, highlighting differences attributable both to the genetic characteristics of the genotypes and to the influence of environmental conditions during the study years. The highest average value was recorded for the Rodica genotype (26.2%), 1.3% higher than the control genotype Xantos (24.9%), indicating a superior potential for the accumulation of reserve proteins in seeds. Relatively high values were also observed in the Aurora (25.6%) and Nicoleta (25.4%) genotypes, while the Evelina (25.0%) and Anastasia (24.9%) genotypes showed levels close to the control. From a biological perspective, these differences reflect the genotypes' ability to utilize available nitrogen and support the metabolic processes involved in protein biosynthesis, given the variability of soil and climate factors during the 2023–2025 period (Table 7).

Table 7.

The Effect of Environmental Conditions on the Protein Content of Peas

No.	Genotype	Protein Content (%)				Difference (%)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	24.7	25.2	24.9	24.9	0.0
2	Evelina	24.8	25.3	25.0	25.0	0.1
3	Rodica	26.0	26.4	26.1	26.2	1.3
4	Aurora	25.2	26.0	25.7	25.6	0.7
5	Nicoleta	25.3	25.5	25.4	25.4	0.5
6	Xantos (control)	24.8	24.9	24.9	24.9	CTRL

The starch content of pea seeds showed relatively little variation across genotypes and years, with values ranging from 49.3% to 50.6% between 2023 and 2025. The highest average values were recorded for the Evelina (50.3%, +0.5% compared to the control) and Anastasia (50.1%, +0.3%) genotypes, indicating a slightly higher capacity for accumulating reserve carbohydrates in seeds. The Nicoleta genotype showed a value close to the control (49.9%, +0.1%), while Aurora (49.8%) had a level similar to that of the Xantos control genotype (49.8%). The lowest average value was observed in the Rodica genotype (49.4%, −0.4% compared to the control). From a biological perspective, these differences reflect the interaction between the genetic potential of the genotypes and the ecological conditions of the study years, with soil and climate

factors influencing the physiological processes involved in starch synthesis and accumulation in seeds (Table 8).

Table 8.

The Effect of Environmental Conditions on the Starch Content of Peas

No.	Genotype	Starch content (%)				Difference (%)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	50.2	50.3	49.9	50.1	0.3
2	Evelina	50.1	50.6	50.3	50.3	0.5
3	Rodica	49.5	49.3	49.4	49.4	-0.4
4	Aurora	49.9	49.7	49.7	49,8	0.0
5	Nicoleta	49.8	50.1	49.7	49.9	0.1
6	Xantos (control)	49.7	49.9	49.8	49.8	CTRL

The lipid content of pea seeds was relatively low, ranging between 1.1% and 1.5% during the 2023–2025 period, reflecting the metabolic characteristics of this legume species, which is characterized by a predominant accumulation of proteins and storage carbohydrates. The highest average value was recorded in the Xantos control genotype (1.5%), while the studied genotypes showed slightly lower values, ranging from 1.1% to 1.4%. Among these, the Anastasia genotype recorded the highest mean value (1.4%, −0.1% compared to the control), followed by the Evelina (1.3%), Rodica, and Nicoleta genotypes (1.2% each), while Aurora exhibited the lowest lipid content (1.1%). The relatively low variability across years suggests good stability of this biochemical trait, with the observed differences being determined by the interaction between the genetic characteristics of the genotypes and the influence of environmental conditions on the metabolic processes involved in the synthesis and accumulation of lipid compounds in seeds (Table 9).

Table 9.

The Effect of Environmental Conditions on the Fat Content of Peas

No.	Genotype	Fat content (%)				Difference (%)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	1.4	1.5	1.4	1.4	- 0.1
2	Evelina	1.3	1.3	1,2	1.3	- 0.2
3	Rodica	1.2	1.2	1.1	1.2	-0.3
4	Aurora	1.2	1.1	1.1	1.1	-0.4
5	Nicoleta	1.1	1.2	1.3	1.2	-0.3
6	Xantos (control)	1.5	1.4	1.5	1.5	CTRL

The ash content of pea seeds, an indicator of total mineral content, ranged from 4.2% to 5.0% between 2023 and 2025. The highest average values were recorded for the Rodica genotype (4.9%, +0.6% compared to the control), followed by Aurora (4.8%, +0.5%) and Nicoleta (4.7%, +0.4%), suggesting a better capacity for mineral accumulation in seeds. The Anastasia and Evelina genotypes showed similar average values (4.6%, +0.3%), but higher than the control (4.3%). The relatively low variability between years indicates good stability of this biochemical trait, with the observed differences reflecting both the genetic characteristics of the genotypes and the influence of environmental conditions on the uptake and translocation of mineral elements during seed formation (Table 10).

Table 10.

The Influence of Environmental Conditions on the Ash Content of Peas

No.	Genotype	Ash content (%)				Difference (%)
		year 2023	year 2024	year 2025	average 2023-2025	
1	Anastasia	4.5	4.7	4.6	4.6	0.3
2	Evelina	4.5	4.6	4.6	4.6	0.3
3	Rodica	4.8	5.0	4.9	4.9	0.6
4	Aurora	4.7	4.9	4.8	4.8	0.5
5	Nicoleta	4.6	4.8	4.7	4.7	0.4
6	Xantos (control)	4.2	4.3	4.3	4.3	CTRL

CONCLUSIONS

Analysis of the growing season revealed differences among the genotypes studied, with Anastasia and Evelina reaching maturity in 81–83 days, while the Rodica and Nicoleta genotypes took a longer period of 88–90 days. This variability reflects both genetic characteristics and the influence of soil and climate factors on the development rate and phenological differentiation of the genotypes.

Plant height of the genotypes ranged from 66 cm to 76 cm, with the Evelina genotype exceeding the Xantos control genotype by 9 cm, indicating superior vegetative capacity and good adaptation to local soil and climate conditions. The differences observed among genotypes highlight the role of genetic interaction with the environment in vegetative growth.

Seed yield and the percentage of dry pods showed high stability in the Anastasia and Evelina genotypes, while the Rodica and Aurora genotypes exhibited progressive declines, suggesting genetic differences in response to thermal and water stress. These characteristics confirm the importance of selecting genotypes with consistent yield and quality performance.

Biochemical analyses of the seeds showed that the Rodica genotype had the highest protein content (26.2%), while the Evelina and Anastasia genotypes had higher starch content, and the ash content was higher in the Rodica and Aurora genotypes, indicating differences in nutrient accumulation and adaptability to variable environmental conditions. Lipid content was consistent and relatively low (1.1–1.4%), a species-specific metabolic trait.

Thousand-seed weight and bulk density showed relative stability in the Evelina and Nicoleta genotypes, while the Rodica and Anastasia genotypes were more sensitive to environmental factors, suggesting that selecting genotypes with high and stable TSW and HW is essential for maximizing production under variable conditions.

Overall, the study's results underscore the importance of selecting genotypes with high ecological adaptability and yield stability (Anastasia and Evelina) for organic and sustainable agriculture, contributing to the optimization of cultivation technologies, increased production, and the strengthening of agricultural systems resilient to soil and climate variability.

AUTHORS CONTRIBUTIONS

Conceptualization, O.C.U., E.U., M.E.F. and B.M.T.; methodology, O.C.U., I.O.S., E.U., M.E.F., B.M.T. and V.T.; data collection O.C.U., E.U., M.E.F. and B.M.T.; data validation, O.C.U., I.O.S., E.U., M.E.F., B.M.T. and V.T.; data processing O.C.U. and V.T.; writing—original draft preparation, O.C.U., V.B. and P.A.B.; writing—review and editing, O.C.U., V.B., P.A.B. and V.T.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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